Soil & Tillage Research 188 (2019) 27–34

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

Promoting "4 Per Thousand" and "Adapting African Agriculture" by south-south cooperation: Conservation agriculture and sustainable intensification

Rattan Lal

Carbon Management and Sequestration Center, The Ohio State University, Columbus, OH 43210, USA

ARTICLE INFO

Keywords:
Soil restoration
Multilateral cooperation
Food security

ABSTRACT

The "4 per Thousand" and "Adapting African Agriculture" are bold and innovative initiatives adopted at COP21 in Paris and COP22 in Marrakesh, respectively. These initiatives are soil-centric and based on adoption of soil-restorative and improved agricultural practices. The objective of this article is to discuss the merits and challenges of South–South Cooperation (SSC) in promoting the adoption of best management practices (BMPs) such as conservation agriculture (CA) and sustainable intensification (SI). Basic principles of CA are: retention of crop residue mulch, incorporation of cover crops and complex rotations, integrated nutrient management and elimination of soil disturbance. The strategy of SI is to produce more from less by enhancing the eco-efficiency, reducing waste, and restoring soil health. Whereas CA has been successfully adopted in Brazil, Argentina, Chile and other regions of South America, its potential of harnessing agronomic and ecologic benefits has not been realized in Sub-Saharan Africa, South Asia, and elsewhere in The Global South. The strategy of SSC is pertinent because of the ten basic principles or tenets: lack of hierarchy, equal participation in all decision-making processes along with transparency, trust, mutual respect, and accountability. However, several concerns have been raised regarding issues such as land grab, and access to resources etc. Based on the scientific concepts of SI, producing more from less, even a triangular cooperation (TAC) or South-South-North (SSNC) cooperation can be developed to achieve adaptation and mitigation of climate change, advance food security, improve degraded soils and restore soil health through soil organic carbon (SOC) sequestration, and advance Sustainable Development Goals (SDGs) of the U.N. A widespread adoption of CA and SI through SSC, TAC or SSNC can advance SDGs including #1 (end poverty), #2 (eliminate hunger), #6 (clean water), #13 (climate action), and #15 (life on land). Of the global cropland area under CA estimated at ~180 million hectare (Mha) in 2015–16, land area under CA is only 2.7 Mha in Africa and 13.2 Mha in Asia. SSC, TAC and SSNC can build upon the existing and on-going initiatives by national and international organizations.

1. Introduction

Soil degradation is a serious issue in the tropics and sub-tropics because of the harsh climate, fragile soils, resource-poor small landholders, and the widespread extractive soil management and low agronomic productivity in the developing countries (Ananda and Herath, 2003), humid tropics (Labriere et al., 2015) and in the West African Sahel (Warren et al., 2001). These problems are aggravated by the high rainfall, wind or climate erosivity (Panagos et al., 2017) in the region which can cause a serious economic loss (Telles et al., 2011; Hansen et al., 2002). Similarly, soil salinization is a major problem, and the risks of salinization may be aggravated by climate change, especially in semi-arid regions and costal areas (Lal, 2010, 2011; Dasgupta et al., 2015; Teh and Koh, 2016). Depletion of soil organic carbon (SOC) concentration and stock may also increase with increase in temperature due to the projected warming (Davidson and Janssens, 2006; Conant et al., 2008) causing a positive feedback to climate change and degradation of soil health. While the world soils are under threat (Montanarella et al., 2016), those of the developing countries have severe consequences to food security for the growing and mostly resource-poor population (Zewdie, 2014; Lobell et al., 2008; Thomspon et al., 2010). Sustainable development of these regions is being jeopardized by the current and projected climate change (Banuri and Opschoor, 2007), and the lack of adoption of proven best management practices (BMPs). Pertinent examples of BMPs include conservation agriculture (CA), sustainable intensification (SI), integration of crops with trees (agroforestry) and livestock (mixed farming) and restoration of soil health through SOC sequestration. Basic components of CA are: (i) crop residue mulch, (ii) elimination of soil disturbance, (iii) cover cropping and complex rotations, and (iv) integrated nutrient management (INM). The goal of SI is to increase productivity (yield) per unit input by enhancing eco-efficiency, reducing losses, and saving land for

E-mail address: lal.1@osu.edu.

https://doi.org/10.1016/j.still.2017.12.015
Received 10 August 2017; Received in revised form 29 November 2017; Accepted 13 December 2017
Available online 01 February 2018
0167-1987/ © 2017 Elsevier B.V. All rights reserved.

nature conservancy. Effectiveness of CA and SI can be enhanced by integration of crops with trees (agroforestry) and livestock (mixed farming). There is a strong need to promote adoption of these BMPs in the Global South.

Soils of Africa and of the Global South are vulnerable to degradation and global warming. These soils have low SOC contents, low plant available water and nutrient reserves, and weak soil structure. Thus, increase in frequency and intensity of extreme events can aggravate vulnerability to erosion, salinization and drought. The vulnerability is exacerbated because small landholders have meagre resources and cannot afford the inputs. Thus, there are two key options to address this problem. One involves the use of innovative ideas and technologies such as the concept of achieving the land degradation neutrality (LDN) proposed by the United Nations Convention to Combat Desertification (Lal et al., 2012). The strategy of LDN is to achieve no net loss of the land-based natural capital following the scientific conceptual framework proposed by Orr et al. (2017) and Cowie et al. (2018). Soil being an important component of land, the long-term goal of achieving land degradation neutrality would also have a synergistic effect on restoring degraded soils. The World Bank group has also undertaken several projects on land restoration including agroforestry (Cook and Grut, 1989; World Bank, 2014, 2016, 2017). Agroforestry has been recommended since 1980s by the International Institute of Tropical Agriculture (IITA) as alley cropping (Kang et al., 1981; Lal, 1989), and by the World Agroforestry Center (ICRAF) since 2000s as the Ever Green Revolution (Swaminathan, 2012; Garrity et al., 2010, 2012). The concept of sustainable land management (SLM) also advances the LDN concept (Smyth and Dumanski, 1995) as it endeavors to minimizing the risks of land degradation, rehabilitating degraded lands and ensuring optimal use of land resources through improvement of soil quality (Carter, 2002). Above all, the relevance of no-till (NT) farming and conservation agriculture (CA) has been emphasized through research on soil erosion control and soil surface management at IITA since 1970s (Lal, 1975, 1983). The research on CA has also been conducted on the dry areas of North Africa by International Center for Agricultural Research in Dry Areas (ICARDA) and national research institutes (Mrabet et al., 2012), and in sub-tropical regions of southern Africa (Thierfelder et al., 2014), and by International Wheat and Maize Improvement Center (CIMMYT) (Wall, 2007). Despite these advances in both basic and applied research, the continental average grain yield in Sub-Saharan Africa has stagnated since 1960s for cereals at 1–1.5 Mg/ha and for grain legumes (pulses) at 0.2–0.5 Mg/ha (Lal, 2016, 2017). The World Bank Group has also undertaken the program called “The West Africa Science Service Center on Climate Change and Adapted Land Use” (WASCAL). It is a largescale educational program on climate change and its effects. It is focused on capacity building and the human resource development, and involves partnership of ten ECOWAS countries. Thus, there is a strong need to build upon these technological advances and translate knowledge into action. In addition to fine-tuning under soil/site-specific conditions, these technologies can also be promoted through modeling, development of decision-based tools, involvement of the farming community through a participatory approach, and incentivization through payments for ecosystem services. These innovations can promote the adoption of climate-smart (climate-resilient agriculture).

This is where the second option is important in which the focus is on adoption through an action-oriented initiative. The strategy is to promote the adoption of these BMPs by the concept of South–South Cooperation (SSC) by involving those developing countries which have been successful in advancing their agriculture through adoption of BMPs. For example, some newly emerging economies (i.e., Brazil, India, South Africa, China) have been successful in enhancing agricultural production through adoption of improved and proven technology. Brazil has been successful in a widespread adoption of CA. The soil conservation movement in Brazil has been widely promoted (de Freitas and Landers, 2014), and CA is practiced on ~35 Mha of cropland in Brazil (Kassam et al., 2015). In addition, CA has also been adopted in other countries in the tropics and sub-tropics, but not so in South Asia and Sub-Saharan Africa. The success of CA in Brazil and South America may be attributed to the system-based approach with due consideration to all components: crop residues mulch, cover crop, integrated nutrient management (INM) and complex crop rotations (Lal, 2015a). Including cover crops in the rotation is critical to the effectiveness of CA (Busscher et al., 1996). Thus, Brazil’s experience can be a great asset in promoting the adoption of CA in Asia and Africa through SSC, triangular cooperation (TAC), or South-South-North Cooperation (SSNC). A similar strategy would be useful in promoting the concept of sustainable intensification (SI) and other BMPs in developing countries.

Therefore, the objective of this article is to deliberate the potential of promoting BMPs (i.e., CA, SI, agroforestry, SLM, LDN) through the strategy of SSC, TAC, SSNC and outline merits and challenges of promoting these strategies in developing countries. The article also discusses the importance of regional differences in biological, socio-economic and cultural factors in adoption of BMPs.

1.1. Climate change and sustainable development

The projected climate change has drastic implications to farmers and land managers (Banuri and Opschoor, 2007), but especially to those in developing countries of the tropics and sub-tropics in Africa (Bryan et al., 2009; Holgate, 2007). The attendant increase in risks of soil degradation in countries of sub-Saharan Africa (Jiang et al., 2014) may worsen the already precarious situation of food security (Jungcurt, 2017). Adverse effects of climate change on food security have been reported in sub-Saharan Africa (Thornton et al., 2009; Adhikari et al., 2015a, 2015b; Nellemann et al., 2009; Ringler et al., 2010), western Africa (Sultan and Gaetani, 2016), central Africa (FAO, 2015; Müller et al., 2011), North Africa (Claussen et al., 2003) and Africa (Challinor et al., 2007). The magnitude of yield decline of food staples with climate change (Table 1) is a global challenge, and can be aggravated by soil degradation in a harsher climate.

Increase in vulnerability of soil to degradation by climate change, and the attendant impacts on agronomic productivity and food security, is also a major challenge for the densely populated countries of Asia, especially those in South Asia (Aggarwal et al., 2011). In fact, the problem of food-security is severe in South Asia and Sub-Saharan Africa (Knox et al., 2012; Jat et al., 2012; Kilroy, 2015) and globally (Sommerville et al., 2014).

While the problems of soil degradation and the adverse impacts of climate change are similar across Asia and Africa, the basic principles and the underpinning concepts in relation to BMPs are also similar. For example, a system-based CA (Lal 2015a,b) would be relevant to both Asia and Africa. Jat et al. (2012) reported that integrated watershed management is an important strategy to mitigate the adverse effects of climate change through soil conservation, improved water availability, integrated genetic resources management and system-based CA practices. Similarly, sustainable agroforestry practices can also enhance

Table 1
Effects of projected climate change on yield of food crops in Africa (Knox et al., 2012; Srivastava et al., 2012; Sultan et al., 2012).

Region	Crop	Yield Decline (%)
Sahel	Maize	12.6
	Millet	10.6
West	Maize	7.4
Central Africa	Maize	13.1
Southern Africa	Maize	11.4
Africa	Wheat	17.2
	Maize	5.4
	Sorghum	14.6
	Millet	9.6

adaptation to climate change (Mbow et al., 2014), and crop models can be used as decision-support tools (Webber et al., 2014).

Climate change, and the associated issues of soil degradation and decline in agronomic yield, are the new security threats for Africa (Brown et al., 2007) and elsewhere. Risks of soil degradation, exacerbated by the increase in intensity and frequency of extreme events, affect civil strife and security through reduction in farm income and increase in unemployment. Soil degradation jeopardizes security by weakening the three pillars of successful societies: inclusive development, rule of law and the respect for human rights (Annan, 2016). Political unrest, civil strife, fanaticism and violence originate in the poorest and most deprived areas of Africa (Annan, 2016). The latter coincide with the regions where soils are degraded, agriculture is weak, and hunger and malnourishment are severe. Depleting SOC pool, degrading soils, recurring drought, marginal use efficiency of fertilizers and other inputs, low crop yields, perpetual poverty and hunger, high infant mortality due to hunger and malnutrition are also real threats to global peace and security because the health of soil, plants, animals, people and ecosystems is one and indivisible. Soil degradation has a severe impact on human health (Kemper and Lal, 2017).

The nexus of climate change-soil degradation-food security is intricately linked with the Sustainable Development Goals (SDGs) of the United Nations, especially SDG #1 (no poverty), #2 (zero hunger), #3 (good health and wellbeing), #6 (clean water), #13 (climate action), and #15 (life on land) (U.N., 2015). Therefore, SOC sequestration and recarbonization of the agroecosystems (biosphere) are important to advancing the SDGs. Any policy intervention to integrate climate change and sustainable development (Banuri and Opschoor, 2007) must also involve soil C sequestration. Soil science is strongly linked to several SDGs through numerous functions and ecosystem services (Keestra et al., 2016). Sequestration of C in soil through CA and other options is a negative-emission strategy of taking CO_2 out of the air.

Including soil C sequestration into strategies to adapt and mitigate climate change and advancing SDGs must also address water resources because of the strong soil-water nexus (Lal et al., 2017). Demands on scarce water resources will increase with intensification of agroecosystems (Pfister et al., 2011), especially in densely-populated watersheds that cross national boundaries—Brahmaputra (Yang et al., 2016) and Niger. The meager water-scarce regions in East Africa (and the Sahel) may become even more scarce because of the climate change (Adhikari et al., 2016). Any successful strategy for adaptation of agroecosystems to climate change should also consider nutrient management, especially N, along with soil and water (Kadyampakeni, 2014). Long-term sustainability of agroecosystems in fragile economies and resource-poor small landholders must address the complex issue of degrading soil quality (physical, chemical, biological and ecological), erratic and uncertain rains, and depleting soil nutrient reserves and dwindling plant available water capacity (PAWC). Thus, restoration of SOC concentration and stocks to an optimal level in the rootzone is of utmost importance (Lal, 2004). It is precisely in this context that the SSC may have an important niche. Water scarcity and the attendant drought, especially the agronomic and pedological drought, are major issues in Sub-Saharan Africa, South Asia and in other arid regions. Adoption of system-based CA can minimize the risks of drought through conservation of water in the rootzone and reduction in soil temperature by residue mulching and elimination of plowing (Lal, 2015a). In this context, adaptation of CA-based technology from Brazil and elsewhere in South America can strengthen the soil-water nexus in harsh and water-scarce regions.

Whereas the research in CA was initiated in early 1970s in all three regions (Sub-Saharan Africa, South America and South Asia), conversion of scientific data into an effective action for its adoption progressed rapidly in South America, especially in Brazil (Speratti et al., 2014). The spread of CA in Brazil has been encouraged by an effective and innovative network of farmers, farmer-managed associations, private-public partnership, CA education and information dissemination, and development of policy support and social capital. Lessons learned from adaptation initiatives of CA in the developing countries (Erenstein et al., 2012) can be used to promote its adaptation elsewhere in the Global South

1.2. South–south cooperation

The SSC encompasses a "broad framework of cooperation among developing countries in political, economic, social, cultural, environmental and technical domains through which developing countries share knowledge, skills, expertise and resources to meet their development goals through concerted efforts" (UN, 2016). It is an important compliment to the North-South Cooperation (NSC), and is being widely promoted for addressing issues such as climate change. However, the NSC is often undermined by inequality which hinders the establishment of "mutually acceptable rules of the game" (Parks and Roberts, 2008). Furthermore, the carbon footprint of the development aid organizations can be large. Almeida et al. (2014) observed that the mobility of staff involves ~60% of the total annual emissions of the organization. Similar to the climate change, issues of food security can also be effectively addressed on a regional basis, such as in South Asia (Khadka, 1990), Sub-Saharan Africa, and Central America, etc.

The merits of SSC in addressing these issues are based on the self-reliance strategy towards developing key benchmark programs (Fig. 1). Four interactive components of such self-reliance programs include: (1) Scientific knowledge and technical knowhow of specific issues such as climate change (i.e., processes, factors, causes, impact, and technological options for adaptation and mitigation), (2) Societal needs for the basic essentials (e.g., energy, water and food), (3) Access to natural resources (e.g., soil, water, vegetation, energy), and (4) Governance (e.g., institutional strength, human resources, policy imperatives) (Fig. 1).

Effectiveness of SSC in addressing regional issues (e.g., adaptation to climate change, food security, water resources management, soil health) depends on ten pillars (Table 2). While equality and hands-off approach are important among pillars, transparency and trust based on respect and accountability are critical criteria of the success of SSC programs. The geographical scope of SSC can be global (Fig. 2a) or regional (Fig. 2b). The goal is to identify transects which cut across a range of ecoregions and biomes (e.g., humid tropics, tropical savannas, semi-arid tropics) and work with farming communities. An important example of regional cooperation based on SSC would be the implementation of the proposal "Adapting African Agriculture" (AAA) proposed at COP22 in Marrakech in November 2016. The strategies of SSC and TAC are also appropriate to advancing the mission of "4 per Thousand" (COP21) proposed in Paris in 2015. The AAA initiative is aimed at reducing vulnerability of Africa's agriculture to climate

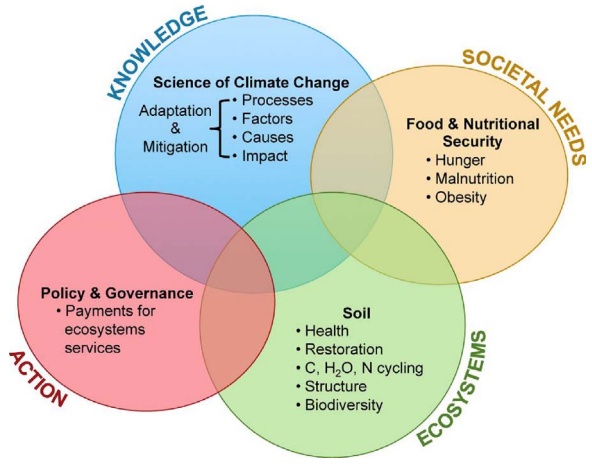

Fig. 1. Four interactive components of self-reliance in South–South Cooperation.

Table 2
Ten pillars of South–South Cooperation.

Criteria	Pillars
• Transparency • Trust • Accountability • Respect	i. Non-hierarchical ii. Horizontal and cooperative, iii. Without conditions or interference, iv. Hands-off approach in the set-up of the cooperation, v. Hands-on approach in the operational phase vi. Peer-to-peer institutional capacity development, vii. Complementary to north-south cooperation, viii. Carries no baggage from the colonial past, and ix. Meets African needs x. Builds upon existing forms of international development

change through fostering and implementation of specific projects on soil restoration, carbon sequestration, water conservation and management, and advancing food security by promoting BMPs of climate-resilient agriculture. The AAA initiative seeks to procure private and public funding to revolutionize the African agriculture. Concepts of SSC and TAC are pertinent to promoting AAA through: (1) building the capacity of African nations to adapt to climate change, and (2) supporting technology transfer and innovation, and measuring and

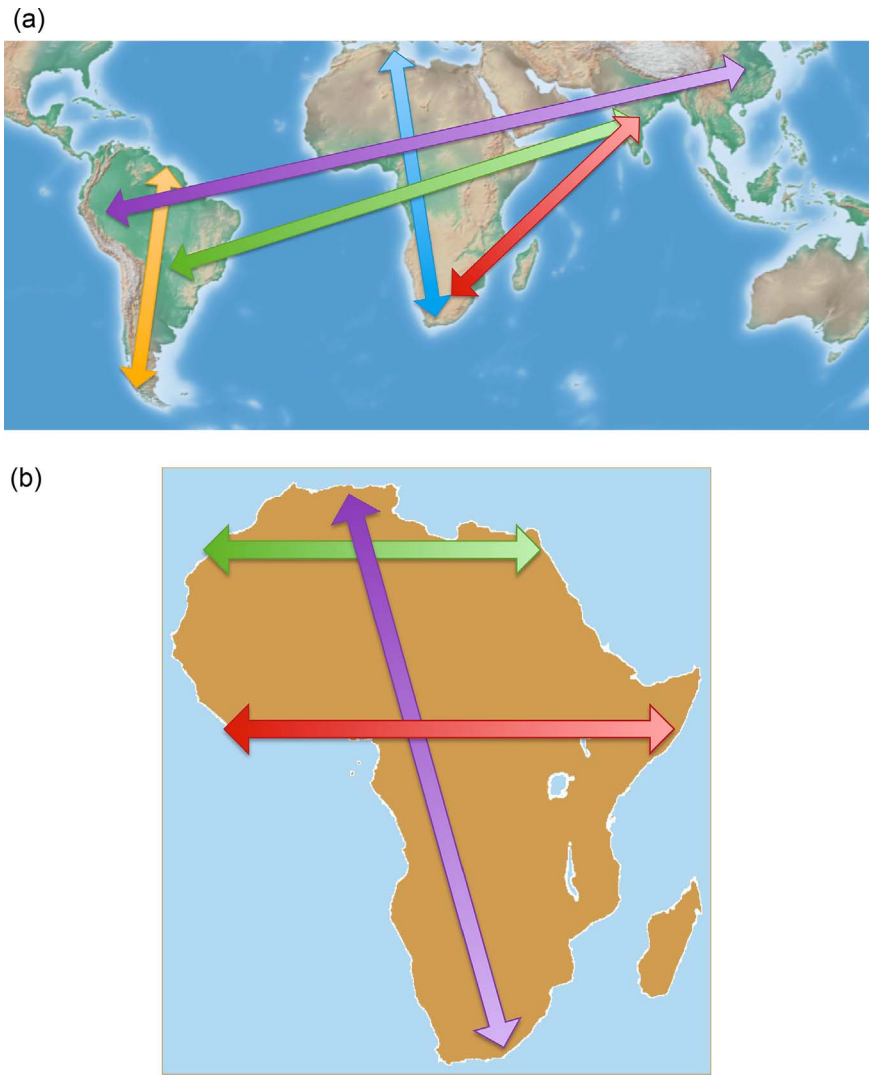

Fig. 2. a. Horizontal transfer of innovative technologies in South–South Cooperation. b. South–South Cooperation within Africa.

monitoring the progress.

The organizers of AAA must capitalize on the willpower, governance ability, and technical support to bring together governments (of African nations), international agencies and technocrats from diverse disciplines to develop a program to adapt and mitigate climate change while improving food security, eliminating malnutrition, alleviating poverty and advancing other SDGs of the UN. Such a program would involve partnership among diverse stakeholders including NGOs, private sector, technocrats/academics, information technology (IT) services, international agricultural research centers, etc. The goal is to integrate communities in diverse ecoregions for implementation of adaptive strategies along the transects exemplified in Fig. 2a and b.

The way forward in SSC must: (1) make it inclusive and engage all/diverse communities of the Global South, (2) promote the science-policy and policy-action nexus, (3) create funds for payments of ecosystems services (e.g., carbon/climate fund, water fund), (4) strengthen communication/dialogue within the South, and (5) involve grassroot communities at local level. Simultaneously, the organizers must safeguard against the risks of: (1) land grab, (2) the water war among neighboring countries, and (3) the virtual water trade aggravated by water-for-food or water-for-energy. Above all, SSC must engage a common understanding of the problems, the development goals and strong partnership. Its effectiveness can be enhanced by making SSC complimentary to TAC or SSNC. Above all, long-term and durable funding support is essential for the successful implementation of the projects within SSC and TAC/SSNC.

2. Promoting Conservation Agriculture and other BMPs through South–South Cooperation

A system-based CA (i.e., mulch, no soil disturbance, INM, cover crop and complex rotations) has numerous advantages to small landholders of Africa. Important among these are: erosion control, water conservation, soil C sequestration in the topsoil, high activity and species diversity of soil biota (micro, meso, and macro), and stable agronomic yield. These are proven advantages in Brazil and elsewhere in South America, especially with regards to low-carbon SI to mitigate climate change and advance food security (Sá et al., 2017). Indeed, countries in South America (e.g., Brazil, Argentina, Chile) have made tremendous progress in science and practice of CA. The total land area under CA in 2015–2016 in South America was 69.9 Mha (Kassam et al., 2017), compared with the global total land area under CA of 179.4 Mha (Table 3). Compared with South America, the cropland area under CA in 2015–2016 was merely 2.7 Mha in Africa and 13.2 Mha in Asia. Most of the land area under CA in Asia was that in China (Lal, 2017). The global land area under CA in 2013 was 157.0 Mha (Kassam et al., 2015). Thus, the global land area under CA increased at the rate of 11.2 Mha/yr over the 2-year period between 2013 and 2015.

Table 3
Global cropland area under conservation agriculture in 2015–2016 (Adapted from Kassam et al., 2017).

Climate	Region	Area under CA (Mha)	% of the world
I. Tropics/Sub-tropics			
	i. South America	69.9	39.0
	ii. Asia	13.2	7.4
	iii. Africa	2.7	1.5
	Sub-total	85.8	47.8
II. Temperature			
	i. North America	63.2	35.2
	ii. Russia/Ukraine	5.2	2.9
	iii. Europe	2.5	1.4
	iv. Australia/New Zealand	22.7	12.7
	Sub-total	93.6	52.2
	Grand Total	179.4	100.0

In South America, the largest land area under CA is in Brazil (~35 Mha), followed by that in Argentina (> 30 Mha) and Paraguay (3.0 Mha) (Table 3). In Brazil, Mr. Herbert Bartz was the pioneer farmer who adopted CA in 1972. The first no-till (NT) planter was built in Brazil in 1975–76, and the first NT conference was held in Ponta Grossa (Parana) in 1981. The evolution of land area under CA in Brazil from 1974 to 2014 is presented by de Freitas and Landers (2014), and the potential of CA for management of light soils in Brazil is presented by Donagemma et al. (2016). Improvements in CA technology over four decades (1975–2015) have enhanced the scope of SI of agroecosystems of the tropics – the management of energy transformation and biochemical cycles of specific plant and animal communities within a landscape to generate delivery of essential ecosystem services (ESs) including food, feed, fiber and fuel.

The expertise in CA from Brazil and other countries in South America can be transferred to similar ecoregions in Africa, Asia, Central America, the Caribbean and elsewhere through SSC. These are examples of successful adoption of CA in southern Africa and elsewhere (Lal, 2015b) and can be spread to neighboring communities through SSC and TAC/SSNC. Brazil is already an important promoter of SSC in Africa (Cost Leite et al., 2013; Marcondes and De Bruyn, 2015), and is also building methodology with focus on sharing its development experiences through horizontal cooperation. However, there are some key differences in agriculture among these regions. For example, CA in Brazil and South America is driven by large-scale commercial farmers and companies, which is not the case in Africa where farming is based on smallholder farmers and there is a lack of investment in technology (e.g., seed drill, weed control). Restoration of soil health, through SOC sequestration and improvement of soil properties, is also a more challenging problem in Sub-Saharan Africa and South Asia than in South America. While the basic principles are known, translating those principles into action through policy intervention and incentivization are major considerations. Therefore, CA has to be fine-tuned to meet the needs of small landholders. Development of seeding equipment through untilled and mulched soil is the critical component. Identification and management of cover crops is another important consideration. Weed control remains to be a major issue, and soil fertility improvement through recycling biowaste and INM have been major issues since 1970s and 1980s (Lal, 1975, 1983).

Rather than a specific soil management technology (such as CA), SSC may also involve implementation of a broad-based concepts of SI of agroecosytems. Such an approach would involve, for example, identification of potential synergies and trade-offs for scenarios to meet food demands and climate change (Palm et al., 2010), or techniques to balance food needs with energy demand (Koning and Mol, 2009). Among other protagonists and promoters of SSC is the Chinese hydropower dams in Cambodia for technology transfer of low-C innovations (Urban et al., 2015),

2.1. Concerns about south–south cooperation

Several concerns have been raised about the effectiveness of international cooperation, especially with regards to the rhetoric and the ground reality of partnership (Schaaf, 2015). There are also issues with regards to green grabbing (Fairhead et al., 2012), land grabbing and materialism of natural capital (Corson et al., 2013). The grabbing may not only be just for resources (e.g., food, finance, energy, water) but also for the geopolitical influence (Sebastian and Warner, 2014), and for access to the market.

It is also argued that promoters of SSC may in fact be seeking resources through new type of diplomacy (Warner, 2015; Stolte, 2012), and acquire new markets for the emerging economies (Amanor, 2013). Incase of the emerging economies, the SSC may also be driven by the intersection between scientific and technological development and domestic policy as in the case of China and India (Stokes et al., 2016).

There are also concerns about applicability of CA, SI, and other

BMPs. Crop residue mulch, integral to a system-based CA, has numerous competing uses. An effective weed control is a major challenge, and soil compaction must be addressed. Similar to CA, SI is also a knowledge-intensive concept. Thus, institutional support and extension services must be strengthened through farmer involvement and cooperation from the planning stages. In this context, motivation and incentivization through payments for provisioning of ecosystem services (e.g., soil C sequestration) may be a critical consideration. These concerns may also be addressed through TAC or SSNC. Furthermore, the list of BMPs can also be expanded to encompass other technologies such as agroforestry, SLM, LDN, etc.

2.2. Towards international cooperation for sustainable management of soil resources

The need for wholistic and sustainable development goes back to the Bruntland Commission (Bruntland, 1987) followed by the Agenda 21 (U.N., 1992), Millennium Development Goals (Bates-Amer et al., 2015), and now the SDGs (U.N., 2015). The aim is to foster international cooperation in research and foreign investment (Tacconi and Tisdell, 1993). Rather than resources or market, the basis of international cooperation should be technological (i.e., scientific technology of sustainable soil management), and innovations for sustainable development (Sharif, 1992). However, the technology transfer must not be unilateral (Yang, 1999), but based on discussion and participatory dialogue among all partners without any hierarchy. De-politicization of a program (Cesarino, 2012) with focus on scientific innovation must be the basis of international cooperation. Due consideration must be also given to the techniques of scaling up of SSC (U.N., 2016) for sustainable development of other regions in the Global South.

With emphasis on science for CA and SI of soils of agroecosystems, TAC and SSNC are also viable options. The TAC involves “southern-driven partnership between two or more developing countries, supported by a developed country(ies) or multilateral organization(s), to implement development cooperation programs and projects” (U.N., 2012). The TAC programs for sustainable soil management should be based on emerging scientific innovations such as CA, soil structure management for reducing risks of compaction and erosion, water conservation in the root zone in conjunction with water harvesting and recycling, drip sub-fertigation, INM, and introduction of new species/varieties adapted to changing climate. Land use and farming must be identified to create a positive soil/ecosystem C budget and based on the concept of SI of “producing more from less” by reducing losses and enhancing use efficiency of inherent and applied resources. Furthermore, principal barriers to adaptation of innovative technologies must be addressed. Impact among these throughout the Global South are: weak human and institutional resources, gender inequality, weak land tenure rights, lack of access to credit and markets, lack of access to scientific information, and lack of enabling environments. Managing C cycle of agroecosystems and making agriculture integral to any solution are better addressed through transparent and trustworthy participation. The strategy is to inhibit part of the C cycle of agroecosystems and create a positive soil C budget. Closely interacting with this strategy is the adoption of soil management systems which enhance the use efficiency of inherent and applied resources.

Agronomic yields of cereals in Sub-Saharan Africa have stagnated at about 1 Mg/ha since 1960s. Thus, food production has not kept pace with that of the population growth. Consequently, attempts at increasing food production are primarily based on horizontal expansion of land area rather than adoption of soil-centric technologies. The SSC must promote soil-centric technologies of SI by improving soil health and restoring degraded and desertified soils, rather than bringing new land under cultivation.

The transect-based concept of validating technologies is applicable to all BMPs including CA, agroforestry, SLM, LDN, etc. The goal is to save land and water resources for nature conservancy, by producing more from less by enhancing eco-efficiency of soil, water, fertilizer, pesticides, and energy.

There are also synergies and trade-offs. Synergies involve the use of wholistic concept and a system-based approach. When soils are degraded, fertility cannot be improved by adding chemical fertilizers, deep plowing, installing terraces, applying water or adding lime. It is the soil health which must be improved through buildup of soil organic matter content, improvement of soil structure and tilth, enrichment of soil biotic activity and species diversity, and enhancement of soil’s water retention capacity. The paradigm shift implies recycling of all plant and animal residues, incorporation of cover crops in the rotation cycle, and elimination of in-field biomass burning. There are also trade-offs. Crop residues must be used as mulch rather than as fuel, animals/cattle must be integrated with crops by adopting forage-based rotations, modern fuel must be made available for cooking so that manure can be used as a soil amendment, in-situ burning must be abolished by providing appropriate seed drills that can cut through the residues, and credit facilities must be available to procure the inputs. The SSC must be based on durable funding and investment opportunities. These challenges must be addressed and converted into opportunities and viable actions.

3. Conclusions

- The existing serious problem of soil degradation in the Global South will be exacerbated by the increasing population and the projected climate change. Thus, food insecurity and the delivery of other ESs will be jeopardized. The traditional system of NSC, used since 1960s, must be revisited in view of the need for a transparent, accountable and southern-driven partnership called SSC, TAC, and SSNC. To be successful and effective, the SSC, TAC, and SSNC must be science-based approaches to promoting adoption of proven technologies developed and widely used in some southern countries. For example, CA is widely used in Brazil and other South American countries and can be an example of SSC.
- Other science-based programs may include some appropriate systems of SI (e.g., INM, water harvesting and recycling based on modern irrigation, soil C sequestration), agroforestry, SLM, LDN, WASCAL etc. The strategy is to build upon and strengthen the existing program.
- The transect-based concept of validating technologies is applicable to all BMPs including CA, agroforestry, SLM, LDN, and others.
- Some barriers to SSC, TAC, and SSNC include weak institutional and human resources, gender inequality, lack of access to credit and market, non-availability of scientific information, and poor enabling environment such as payments for delivery of ESs.
- In addition to building human resources, promoting stewardship of soil and other natural resources must be integral component of education and communication. Soil stewardship and care must be embedded in every fruit and vegetable eaten, in each grain ground into the bread consumed, in every cup of water used, in every breath of air inhaled, and in every scenic landscape cherished.

References

Adhikari, U., Nejadhashemi, A., Herman, M., 2015a. A review of climate change impacts on water resources in east Africa. Trans. Asabe 58 (6), 1493–1507.
Adhikari, U., Nejadhashemi, A., Woznicki, S., 2015b. Climate change and eastern Africa: a review of impact on major crops. Food Energy Secur. 4 (2), 110–132.
Adhikari, U., Nejadhashemi, A.P., Herman, M.R., 2016. A review of climate change impacts on water resources in East Africa. ASABE 58 (6), 1493–1507.
Aggarwal, P., Sivakumar, M., Lal, R., Faiz, S., Rahman, A., Islam, K., 2011. Global climate change and food security in south asia: an adaptation and mitigation framework. Clim. Change Food Secur. South Asia 253–275.
Almeida, J., Verbist, B., Achten, W., Maertens, M., Muys, B., 2014. Sustainability in development cooperation: preliminary findings on the carbon footprint of development aid organizations. Sustain. Dev. 22 (5), 349–359.
Amanor, K.S., 2013. South–South Cooperation in Africa: historical, geopolitical and political economy dimensions of international development. IDS Bull. 44, 4.

Ananda, J., Herath, G., 2003. Soil erosion in developing countries: a socio-economic appraisal. J. Environ. Manag. 68 (4), 343–353.
Annan, K., 2016. Africa and the global security architecture. In: Tana High Level Forum on Security in Africa. 16–17 April 2016, Bahir Dar, Ethiopia.
Banuri, T., Opschoor, H., 2007. Climate Change and Sustainable Development. DESA Working Paper No. 56. United Nations Department of Economic and Social Affairs, New York, NY.
Bates-Amer, N., Carin, B., Lee, M.H., Lim, W., 2015. Post 2015 Development Agenda: Goals, Targets and Indicators. CIGI/KDI, Ontario.
Brown, O., Hammill, A., Mcleman, R., 2007. Climate change as the 'new' security threat: implications for Africa. Int. Aff. 83 (6), 1141–1154.
Bruntland, G.H., 1987. Brundtland Report: Our Common Future. World Commission on Environment and Development. U.N., New York.
Bryan, E., Deressa, T., Gbetibouo, G., Ringler, C., 2009. Adaptation to climate change in Ethiopia and South Africa: options and constraints. Environ. Sci. Policy 12 (4), 413–426.
Busscher, W.J., Reeves, W., Kocham, R.A., Bauer, P.J., Mullins, G.L., Clapham, W.M., Kemper, W.D., 1996. Conservation farming in southern Brazil: using cover crops to decrease erosion and increase infiltration. J. Soil. Water Conserv. 51, 188–192.
Carter, M.R., 2002. Soil quality for sustainable land management: organic matter and aggregation interactions that maintains soil functions. Agron. J. 94, 38–47.
Cesarino, L., 2012. Anthropology of development and the challenge of South–South Cooperation. Vibrant 9, 507–537.
Challinor, A., Wheeler, T., Garforth, C., Craufurd, P., Kassam, A., 2007. Assessing the vulnerability of food crop systems in Africa to climate change. Clim. Change 83 (3), 381–399.
Claussen, M., Brovkin, V., Ganopolski, A., Kubatzki, C., Petoukhov, V., 2003. Climate change in northern Africa: the past is not the future. Clim. Change 57 (1–2), 99–118.
Conant, R., Drijber, R., Haddix, M., Parton, W., Paul, E., Plante, A., Six, J., Steinweg, J., 2008. Sensitivity of organic matter decomposition to warming varies with its quality. Glob. Change Biol. 14 (4), 868–877.
Cook, C.C., Grut, M. 1989. Agroforestry in Sub-Saharan Africa. World Bank Paper #12, Washington, D.C., 94 pp.
Corson, C., MacDonald, K.I., Neimark, B., 2013. Grabbing green: markets, environmental governance and the materialization of natural capital. Hum. Geogr. New Rad. J. 6 (1), 1–15.
Cost Leite, I., Suyama, B., Pomeroy, M., 2013. Africa-Brazil cooperation in social protection: drivers, lessons, and shifts in the engagement of the Brazilian ministry of social development. WIDER working paper, No. 2013/022, Helsinki: UNU-WIDER.
Cowie, A.L., Orr, B.J., Sanchez, V.M.C., Chasek, P., Crossman, N.D., Erlewein, A., Louwagie, G., Maron, M., Metternicht, G.I., Minelli, S., Tengberg, A.E., Walter, S., Walton, S., 2018. Land in balance: the scientific conceptual framework of land degradation neutrality. Environ. Sci. Policy 79, 25–35.
Dasgupta, S., Hussain, M.M., Huq, M., Wheeler, D., 2015. Climate change and soil salinity: the case of coastal Bangladesh. Ambio 44 (8), 815–826.
Davidson, E., Janssens, I., 2006. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. Nature 440 (7081), 165–173.
de Freitas, P.L., Landers;1, J.N., 2014. The transformation of agriculture in Brazil through development and adoption of zero tillage conservation agriculture. Int. Soil Water Conserv. Res. 2, 35–46.
Donagemma, G., De Freitas, P., Balieiro, F., Fontana, A., Spera, S., Lumbreras, J., Viana, J., De Araujo, J., Dos Santos, F., De Albuquerque, M., Macedo, M., Teixeira, P., Amaral, A., Bortolon, E., Bortolon, L., 2016. Characterization, agricultural potential, and perspectives for management of light soils in Brazil. Pesq. Agropec. Bras. 51 (9), 1003–1020.
Erenstein, O., Sayre, K., Wall, P., Hellin, J., Dixon, J., 2012. Conservation agriculture in maize and wheat-based systems in the (sub)tropics: lessons from adaptation initiatives in South Asia, Mexico, and Southern Africa. J. Sust. Agric. 36, 180–206.
FAO, 2015. The State of Food Insecurity in the World. DAO/IFAD/World Food Program. FAO, Rome, Italy.
Fairhead, J., Leach, M., Scoones, I., 2012. Green grabbing: a new appropriation of nature. J. Peasant Stud. 39 (2), 237–261.
Garrity, D., Akinnifesi, F.K., Ajayi-Sileshi, O.C., Weldesemayat, G., Mowo, J.G., Kalinganire, A., Larwanou, M., Bayala, J., 2010. Evergreen agriculture: a robust approach to sustainable food security in Africa. Food Secur. 2 (3), 197–214.
Garrity, D., Dixon, J., Boffa, J.M., 2012. Understanding African farming systems: science and policy implications. In: Australian Center for International Agricultural Research (ACIR), Food Security in Africa: Bridging Research and Practice. 29–30 November 2012, Sydney Australia.
Hansen, L., Breneman, V., Davison, C., Dicken, C., 2002. The cost of soil erosion to downstream navigation. J. Soil Water Conserv. 57 (4), 205–212.
Holgate, C., 2007. Factors and actors in climate change mitigation: a tale of two South African cities. Int. J. Justice Sustain. 12 (5), 471–484.
Jat, R., Craufurd, P., Sahrawat, K., Wani, S., 2012. Climate change and resilient dryland systems: experiences of ICRISAT in Asia and Africa. Curr. Sci. 102 (12), 1650–1659.
Jiang, B., Bamutaze, Y., Pilesjö, P., 2014. Climate change and land degradation in Africa: a case study in the Mount Elgon region, Uganda. Geo-spatial Inf. Sci. 17 (1), 39–53.
Jungcurt, S., 2017. FAO Assesses Food Security in Africa. http://sdg.iisd.org/news/fao-assesses-food-security-in-africa/.
Kadyampakeni, D., 2014. Soil, water, and nutrient management options for climate change adaptation in southern africa. Agron. J. 106 (1), 100–110.
Kang, B.T., Wilson, G.F., Sipkens, L., 1981. Alley cropping maize and lencaenca in southern Nigeria. Plant Soil 63, 165–179.
Kassam, A., Friedrich, T., Derpsch, R., Kienzle, J., 2015. Overview of the worldwide spread of conservation agriculture. Field Action Sci. Rep. 8 (online).
Kassam, A., Friedrich, T., Derpsch, R., 2017. Global spread of conservation agriculture: interim update 2015–2016. In: 7th World Congress of Conservation Agriculture. 1–4 August 2017, Rosario, Argentina.
Keestra, S.D., Bouma, J., Wallinga, J., Tittonell, P., Smith, P., Cerda, A., Montanarella, L., Quinton, J.N., Pachepsky, Y., Van der Putten, W.H., Bardgett, R.D., Moolenaar, S., Mol, G., Jansen, B., Fresco, L.O., 2016. The significance of soil and soil science towards realization of the United National Sustainable Development Goals. Soil 2, 111–128.
Kemper, K., Lal, R., 2017. Pay dirt: human health depends on soil health. Compl. Therap. Med. 32, A1–A2.
Khadka, N., 1990. Regional cooperation for food security in South-Asia. Food Policy 15 (6), 492–504.
Kilroy, G., 2015. A review of the biophysical impacts of climate change in three hotspot regions in Africa and Asia. Reg. Environ. Change 15 (5), 771–782.
Knox, J., Hess, T., Daccache, A., Wheeler, T., 2012. Climate change impacts on crop productivity in Africa and South Asia. Environ. Res. Lett. 7 (3).
Koning, N., Mol, A.P.J., 2009. Wanted: institutions for balancing global food and energy markets. Food Secur. 1 (3), 291–303.
Labriere, N., Locatelli, B., Laumonier, Y., Freycon, V., Bernoux, M., 2015. Soil erosion in the humid tropics: a systematic quantitative review. Agric. Ecosyst. Environ. 203, 127–139.
Lal, R., Safriel, U., Boer, B., 2012. Zero Net Land Degradation. UNCCD Position Paper for Rio + 20. Bonn, Germany.
Lal, R., Mohtar, R.H., Assi, A.T., Ray, R., Baybil, H., JahnM, M., 2017. Soil as a basic nexus tool: soils at the center of the food-energy-water nexus. Curr. Sustain. Renew. Energy Rep. 4, 1–13.
Lal, R., 1975. Role of mulching techniques in tropical soil and water management. IITA Tech. Bull. 1 (38 pp).
Lal, R.,1983. No-till Farming: Soil and water conservation and management in the humid and subhumid tropics. IITA Technical Bulletin Series, Monograph 2, 64 pp.
Lal, R., 1989. Agroforestry systems and soil surface management of a tropical Alfisol. V. Water infiltrability, transmission and soil water sorptivity. Agrofor. Syst. 8, 217–238.
Lal, R., 2004. Soil carbon sequestration impacts on global climate change and food security. Science 304, 1623–1627.
Lal, R., 2010. Carbon sequestration in saline soils. J. Soil Salin. Water Qual. 1 (1–2), 30–40.
Lal, R., 2011. Land degradation and pedological processes in a changing climate. Pedologist 315–325.
Lal, R., 2015a. A system approach to conservation agriculture. J. Soil Water Conserv. 70 (4), 82A–88A.
Lal, R., 2015b. Sequestering carbon and increasing productivity by conservation agriculture. J. Soil Water Conserv. 70 (3), 55A–62A.
Lal, R., 2016. Potential and challenges of conservation agriculture in sequestration of atmospheric CO2 for enhancing climate-resilience and improving productivity of soil of small landholder farms. CAB Rev. 11, 009. http://dx.doi.org/10.1079/PAVSNNR201611009.
Lal, R., 2017. Improving soil health and human protein nutrition by pulses-based cropping systems. Adv. Agron. 145, 167–204.
Lobell, D., Burke, M., Tebaldi, C., Mastrandrea, M., Falcon, W., Naylor, R., 2008. Prioritizing climate change adaptation needs for food security in 2030. Science 319 (5863), 607–610.
Müller, C., Cramer, C., Hare, W.L., Lotze-Campen, H., 2011. Climate change risks for African agriculture. Proc. Natl. Acad. Sci. 108, 4313–4315.
Marcondes, G., De Bruyn, T., 2015. Brazil's South–South Cooperation in food security Capacity building approaches of the Centre of Excellence against hunger. Food Secur. 7 (6), 1153–1164.
Mbow, C., Smith, P., Skole, D., Duguma, L., Bustamante, M., 2014. Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. Curr. Opin. Environ. Sustain. 6, 8–14.
Montanarella, L., Pennock, D.J., McKenzie, N., Badraoui, M., Chude, V., Baptista, I., Mamo, T., Yemefack, M., Aulakh, M.S., Yagi, K., Hong, S.Y., Vijarnsorn, P., Zhang, G.L., Arrouays, D., Black, H., Krasilnikov, P., Sobocká, J., Alegre, J., Henriquez, C.R., de Lourdes Mendonça-Santos, M., Taboada, M., Espinosa-Victoria, D., AlShankiti, A., AlaviPanah, S.K., El Mustafa Elsheikh, E.A., Hempel, J., Arbestain, M.C., Nachtergaele, F., Vargas, R., 2016. Worldás soils are under threats. Soil J. 2, 79–82.
Mrabet, R., Moussadek, R., Fadlasdri, A., Van Ranst, E., 2012. Conservation agriculture in dry areas of Morocco. Field Crop Res. 132, 84–94.
Nellemann, C., MacDevette, M., Manders, T., Eickhout, B., Svihus, B., Prins, A. G., Kaltenborn, B. P. (Eds). 2009. The environmental food crisis – the environment's role in averting future food crises. A UNEP rapid response assessment. United Nations Environment Programme, GRID-Arendal, www.grida.no.
Orr, B.J., Cowie, A.L., Sanchez, V.M.C., Chasek, P., Crossman, N.D., Erlewein, A., Louwagie, G., Maron, M., Metternicht, G.I., Minelli, S., Tengberg, A.E., Walter, S., Walton, S., 2017. Scientific Conceptual Framework for Land Degradation Neutrality: A Report for the Science-Policy Interface. UNCCD, Bonn, Germany (130 pp).
Palm, C., Smukler, S., Sullivan, C., Mutuo, P., Nyadzi, G., Walsh, M., 2010. Identifying potential synergies and trade-offs for meeting food security and climate change objectives in sub-Saharan Africa. Proc. Natl. Acad. Sci. U. S. A. 107 (46), 19661–19666.
Panagos, P., Borrelli, P., Meusburger, K., Yu, B., Klik, A., Lim, K., Yang, J., Ni, J., Miao, C., Chattopadhyay, N., Sadeghi, S., Hazbavi, Z., Zabihi, M., Larionov, G., Krasnov, S., Gorobets, A., Levi, Y., Erpul, G., Birkel, C., Hoyos, N., Naipal, V., Oliveira, P., Bonilla, C., Meddi, M., Nel, W., Al Dashti, H., Boni, M., Diodato, N., Van Oost, K., Nearing, M., Ballabio, C., 2017. Global rainfall erosivity assessment based on high-temporal resolution rainfall records. Sci. Rep. 7.
Parks, B., Roberts, J., 2008. Inequality and the global climate regime: breaking the north-south impasse. Cambridge Rev. Int. Aff. 21 (4), 621–648.
Pfister, S., Bayer, P., Koehler, A., Hellweg, S., 2011. Projected water consumption in

future global agriculture: scenarios and related impacts. Sci. Total Environ. 409 (20), 4206–4216.
Ringler, C., Zhu, T., Cai, X., Koo, J., Wang, D., 2010. Climate Change Impacts on Food Security in Sub-Saharan Africa. Environment and Production Technology Division, IFPRI, Washington, D.C.
Sá, J.C.M., Lal, R., Cerri, C.C., Lorenz, K., Hungria, M., Carvalho, P.C.F., 2017. Low-carbon agriculture in South America to mitigate global climate change and advance food security. Environ. Int. 98, 102–112.
Schaaf, R., 2015. The rhetoric and reality of partnerships for international development. Geogr. Compass 9 (2), 68–80.
Sebastian, A.G., Warner, J.F., 2014. Geopolitical drivers of foreign investment in Africa land and water resources. Afr. Identities 12 (1), 8–25.
Sharif, N., 1992. Technological dimensions of international-cooperation and sustainable development. Technol. Forecast. Soc. Change 42 (4), 367–383.
Smyth, A.J., Dumanski, J., 1995. A framework for evaluating sustainable land management. Can. J. Soil. Sci. 75, 401–406.
Sommerville, M., Essex, J., Le Billon, P., 2014. The 'global food crisis' and the geopolitics of food security. Geopolitics 19 (2), 239–265.
Speratti, A., Turmel, M.S., Calegari, A., Araujp-Junior, C.F., Violic, A., Wall, P., Govaerts, B., 2014. Conservation agriculture in Latin America. In: Farooq, M., Siddique, K.H.M. (Eds.), Conservation Agriculture. Springer International Publishing, Switzerland, pp. 391–415.
Srivastava, A., Gaiser, T., Paeth, H., Ewert, F., 2012. The impact of climate change on Yam (Dioscorea alata) yield in the savanna zone of West Africa. Agric. Ecosyst. Environ. 153, 57–64.
Stokes, L., Giang, A., Selin, N., 2016. Splitting the south: China and India's divergence in international environmental negotiations. Global Environ. Polit. 16 (4), 12–31.
Stolte, C., 2012. Brazil in Africa: Just Another BRICS Country Seeking Resources? Chatham House Briefing Paper AFP/AMP BP 2012/01. Royal Institute of International Affairs, London (November).
Sultan, B., Gaetani, M., 2016. Agriculture in West Africa in the twenty-first century: climate change and impacts scenarios, and potential for adaptation. Frontiers in Plant Science 7, Article 1262.
Sultan, B., Guan, K., Kouressy, M., Biasutti, M., Piani, C., Hammer, G.L., McLean, G., Lobell, D.B., 2012. Robust features of future climate change impacts on sorghum yields in West Africa. Environ. Res. Lett. 9. http://dx.doi.org/10.1088/1748-9326/9/10/104006.
Swaminathan, M.S., 2012. Agroforestry for an evergreen revolution. In Nair, P.K., Garrity, D.J. (Eds) Agroforestry: The Future of Global Land Use. ADAG, Volume 9, Springer Dordrecht, pp. 7–10.
Tacconi, L., Tisdell, C., 1993. Holistic sustainable development: implications for planning, processes, foreign aid and support for research. Third World Plan. Rev. 15, 411–428.
Teh, S.Y., Koh, H.L. 2016. Climate change and soil salinization: impact on agriculture, water and food security. Int. J. Agric. Forestry & Plantations 2, ISNN 2462-1757.
Telles, T., Guimaraes, M., Dechen, S., 2011. The costs of soil erosion. Rev. Bras. Cien. Solo 35 (2), 287–298.
Thierfelder, C., Rusinamhodzi, L., Ngwira, A.R., Mupangwa, W., Nyagumbo, I., Kassie, G.T., Carins, J.E., 2014. Conservation agriculture in southern Africa: advances in knowledge. Renew. Energy Food Syst. http://dx.doi.org/10.1017/S1742/70513000550). (21 pp).
Thomspon, H.E., Berrang-Ford, L., Ford, J.D., 2010. Climate change and food security in sub-Saharan Africa: a systematic literature review. Sustainability 2, 2719–2733.
Thornton, P., Jones, P., Alagarswamy, G., Andresen, J., 2009. Spatial variation of crop yield response to climate change in East Africa. Global Environ. Change Hum. Policy Dimens. 19 (1), 54–65.
U.N., 1992 Conference on Environment and Development, Rio de Janerio, 3–14 June 1992, Agenda 21.
U.N., 2012. South–South cooperation for development. United Nations, High-level Committee on South0South Cooperation, Seventeenth Session, SSC/17/3, 22–25 May 2012.
U.N., 2015. Transforming Our World: the 2030 Agenda for Sustainable Development. 25–27 September, New York.
U.N., 2016. Scaling-up South–South Cooperation for sustainable development. United Nations Development Programme, Bureau for Policy and Programme Support, New York, 1–23.
Urban, F., Siciliano, G., Sour, K., Lonn, P., Tan-Mullins, M., Mang, G., 2015. South–South technology transfer of low-carbon innovation: large chinese hydropower dams in Cambodia. Sustain. Dev. 23 (4), 232–244.
Wall, P.C., 2007. Tailoring conservation agriculture to the needs of small farmers in developing countries. J. Cop. Improv. 19, 137–155.
Warner, J., 2015. South–South cooperation: Brazilian soy diplomacy looking East? Food Security 7 (6), 1175–1185.
Warren, A., Batterbury, S., Osbahr, H., 2001. Soil erosion in the West African Sahel: a review and an application of a local political ecology; approach in South West Niger. Glob. Environ. Change-Hum. Policy Dimens. 11 (1), 79–95.
Webber, H., Gaiser, T., Ewert, F., 2014. What role can crop models play in supporting climate change adaptation decisions to enhance food security in Sub-Saharan Africa? Agric. Syst. 127, 161–177.
World Bank, 2014. Restoring Lands, Lives, and Livelihood in Africa. World Bank, Washington D.C.
World Bank, 2016. Africa's Bold and Ambitious Endeavor: Restoring 100 M Hectares of Land by 2030. World Bank, Washington, D.C.
World Bank, 2017. An Integrated Approach to Managing and Restoring Landscapes. World Bank, Washington D.C.
Yang, Y., Wi, S., Ray, P., Brown, C., Khalil, A., 2016. The future nexus of the Brahmaputra River Basin: climate, water, energy and food trajectories. Global Environ. Change-Hum. Policy Dimens. 37, 16–30.
Yang, Z., 1999. Should the north make unilateral technology transfers to the south? North-South cooperation and conflicts in responses to global climate change. Resour. Energy Econ. 21 (1), 67–87.
Zewdie, A., 2014. Impacts of climate change on food security: a literature review in sub Saharan Africa. Earth Sci. Clim. Change 5 (8), 1000225.